The Etiology and Control of Root and Stem Rots of Peas in Washington

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INTRODUCTION

The production of peas is of considerable economic importance in Washington. The Palouse area (including especially Whitman and Spokane counties) is particularly adapted to the production of dry peas; and the Blue Mountain area, consisting of Columbia, Walla Walla, Garfield, and Asotin counties, to canning peas. For the ten-year period 1934-1943, the average acreage of processing peas for the Blue Mountain region was about 20,000 acres, with an average annual production of 22,000 tons. Since 1943 the acreage has been increased to 40,000. During the ten-year period 1931-1940, an average of 104,000 acres of dry peas was harvested annually. The average annual production during these years was approximately 2,000,000 bushels, which is about one-half of the total production of dry peas in the United States. In recent years the acreage in dry peas has increased to 350,000 in 1944 and 200,000 in 1945.

One of the major factors in the production of peas in the state is seed decay and root and stem rotting. Losses as high as 50 per cent have been reported in eastern Washington (*3*)[3] due to these diseases. Investigations were needed of the effect of seed treatment as a possib'e means of control of these diseases, the identity and source of the specific organisms involved, and the effects of other factors on the incidence of disease. This study has been a major project of the Washington Agricultural Experiment Stations since the fall of 1942.

In the present investigations, seed-treatment experiments and factors affecting the incidence of the diseases were given due consideration. In addition to numerous field surveys and plot experiments, studies were carried on in the laboratories, mills, and greenhouses at Pullman and Dayton, Washington.

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[2] Formerly Research Assistant in Plant Pathology. Grateful acknowledgments are made to Dr. J. G. Harrar, under whom these investigations were initiated; to Dr. E. J. Anderson, with whom the study was continued; to Dr. George W. Fischer, for helpful suggestions and criticisms in the preparation of the manuscript; to Dr. S. P. Swenson, Dr. L. K. Jones, and Dr. C. L. Vincent, for suggestions and criticisms of the work; and to Dr. W. C. Snyder of the University of California and Dr. J. R. Gilman of Iowa State College, for specific identification of certain cultures of fungi.

[3] Figures within parentheses refer to "Literature Cited," page 42.

NATURE AND IMPORTANCE OF ROOT AND STEM ROTS OF PEAS

The root and stem rots are among the most important diseases of peas in Washington because of the frequent cool, damp springs which are unfavorable for seed germination. Root rot increases in older pea-growing areas, especially where proper rotation methods are not followed. Much of the losses previously assigned to wilt should in all probability be attributed to root rot because of the similarity of symptoms.

Various workers in the midwestern and eastern United States have made extensive investigations of root rot and have stressed the significance of these diseases, particularly in older pea-growing centers.

Peas are attacked in any stage of development, but the "damping off" of seedlings is one of the most serious of the diseases. One may not be aware of the actual prevalence of damping-off, since the most important phase of this disease, the pre-emergence phase, is inconspicuous. That is, the young seedlings are killed before emergence from the ground. Thus poor stands, usually attributed to inferior seed, actually may be due to the activities of pathogenic fungi prior to the emergence of the growing seedlings.

The post-emergence phase of damping-off is characterized by a toppling over of the seedling anytime after it emerges from the soil and until the stem "hardens." The stem becomes discolored and shrivelled at the soil line and thus is too weak to support the upper growth. Seedlings that appear healthy one day may collapse by the next morning. Though better known to most pea growers, this phase of the disease is less common than the pre-emergence stage.

Root and stem rots of older plants may be caused by some of the damping-off fungi (Fig. 1). In some cases, certain fungi were found to be capable of causing only damping-off; in other instances, they could also produce root and stem rots. For example, if pea seedlings are infected when still succulent, the young plants soon collapse and die. If infection occurs after the seedlings have begun to "harden," the infected plants do not generally collapse but instead become stunted and as a result are of little economic value.

The invaded areas of the root and stem become discolored. Root rot occurs on the roots and sometimes a short distance up the stem. The lower part of the stem in the region of the attachment of the seed may be the point of infection, and then the fungus may grow in both directions, turning the invaded area greyish-brown, chocolate, or black; occasionally some lesions are reddish and are in the form of streaks on the taproot or on the stem near the ground line.

Later these spots or streaks enlarge, deepen, and unite. In mature plants, yellowing and browning of the leaves and bases of the vines results. The attacked areas decay and the vines die. At low soil temperatures the connection between root and stem may be completely

Fig. 1.—Appearance of seed decay and root and stem rots of peas in Washington.

decayed, forcing the plant to depend upon the roots which are developed above the decayed region. At high soil temperatures the vascular bundles turn a characteristic reddish-brown and the plant wilts. This may be confused with true wilt. However, in wilt the roots appear normal in outward appearance. Furthermore, most of the strains of peas used in eastern Washington are more or less resistant to true wilt.

The interrelationship between damping-off and root and stem rots of peas should emphasize the complexity of the entire disease problem as well as the value of producing healthy seedlings.

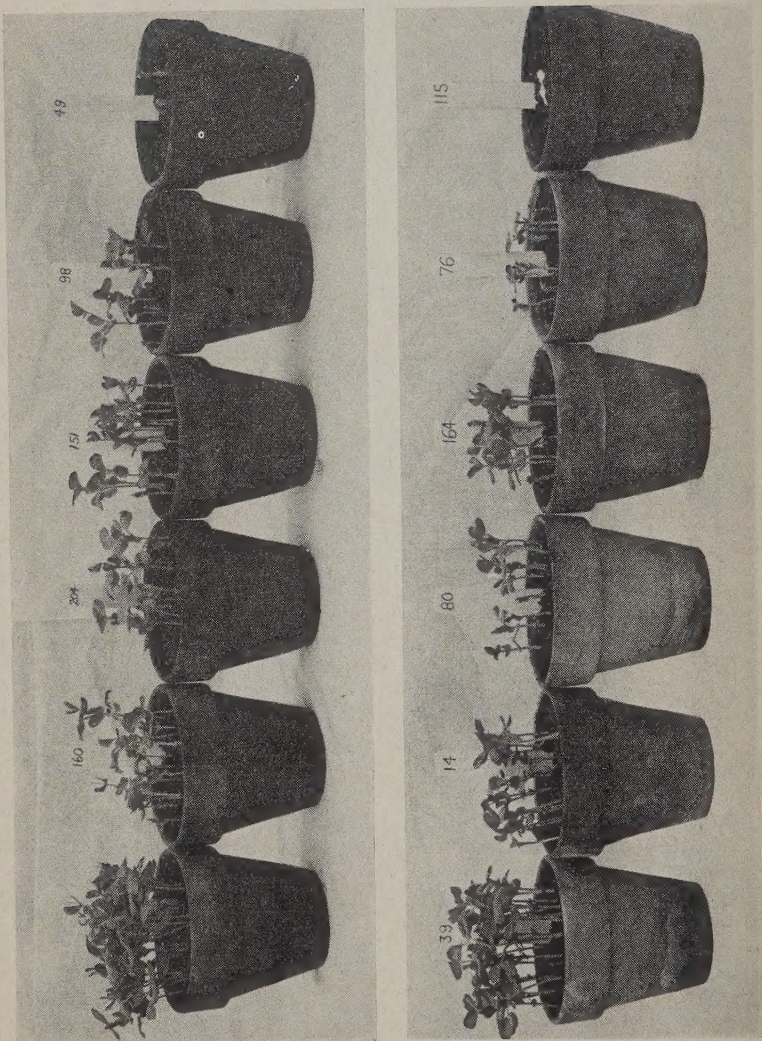

Fig. 2—Variation in pathogenicity of certain pea isolates.

CAUSE OF ROOT AND STEM ROTS OF PEAS

Root and stem rots of peas in pea-growing areas of the world have been found to be due to many different organisms. The number recorded in the literature are too numerous to mention. However, those organisms generally associated with the diseases are as follows: *Fusarium martii,* App. and Woll. var. *pisi* Jones (*Fusarium solani* f. *pisi* Jones (Sny. et H.), *Aphanomyces euteiches* Drechs., *Corticium vagum* Berk. and Curt., *Pythium ultimum* Trow, *Ascochyta pinodella* L. K. Jones, *Mycosphaerella pinodes* Berk. and Blox., *Sclerotinia sclerotiorum* (Lib.) Mass., *Thielavia basicola* (Berk. and Br.) Zopf., and *Sclerotium rolfsii* Sacc. Padwick (*12*) mentions several Fusaria in the wilt group that can cause slight root and foot rot. In addition he refers to fifteen other species of Fusarium that have been mentioned in literature as causing root or foot rot of peas.

In order to determine the causative agents of root and stem rots of peas in Washington, isolations were made from the seed and from decayed roots and stems of peas grown in the Blue Mountains and Palouse areas of the state. A total of 377 isolates were obtained during the years 1942-1945, inclusive. These were isolated both from the seed and from pea plants grown in the greenhouse and in the field. In the preliminary pathogenicity tests conducted in 1943 and 1944, 42 of the isolates were single-spored, and the resulting pure cultures were tested for their pathogenicity on peas (Table 1). These showed varying degrees of virulence (Fig. 2). The data showed that soil-borne organisms were of the greater importance in causing the diseases, although the microflora of the seed could not be entirely discounted. Cultures numbered 75, 76, 77, and 115 were isolated from seed.

This study has shown that several species of fungi are responsible for root and stem rots of peas in Washington. The chief causative agent is *Fusarium solani* f. *pisi* which was identified in 188 of the 377 isolations made, representing about 50-per-cent occurrence. This fungus was consistently isolated (106 of 178 isolations) from seedlings and plants during the course of the growing season, giving further evidence of its importance. Some strains of this organism are capable of causing damping-off as well as root and stem rots and in other cases they cause only root and stem rots (Fig. 3).

A Sclerotinia culture has also proven to be virulent on peas. It causes severe damping-off, as well as root and stem rot, the lesions being almost black in color. The sclerotia upon germination in sand medium produced apothecia characteristic of Sclerotinia. The organism was isolated in 1943 from pea pods on vines that were cut and drying in the field near Garfield. This fungus does considerable damage during warm, humid weather.

Another organism causing the diseases in Washington is a species of Phoma obtained from the seed and diseased roots and stems of peas. It was tentatively classified as belonging to the *Phoma conidiogena* com-

Table 1.—Pathogenicity tests of pure cultures of original isolates numbered from 20 to 115.

Culture data		Inoculation results				
		No. of plants showing				
Culture number	Identity of causal organism	Emergence	Tip blight	Stem lesion	Root decay	Severity of lesions
		%	%	%	%	
20	Verticillium sp.	93	—	16	16	Very slight
22	Verticillium sp.	98	—	7	5	"
23	Verticillium sp.	99	—	10	11	"
24	Verticillium sp.	96	—	24	10	"
25	Verticillium sp.	98	—	4	1	"
26	Verticillium sp.	100	—	1	5	"
27	Verticillium sp.	97	—	—	—	"
30	Verticillium sp.	99	—	—	—	"
32	Fusarium solani f. pisi	100	—	7	34	Slight-moderate
33	F. solani f. pisi	100	—	33	38	Severe
35	F. equiseti	87	3	17	28	Very slight
37	F. oxysporum	98	—	1	36	Slight-moderate
38	F. solani f. pisi	78	—	35	45	Moderate
39	F. solani f. pisi	98	—	7	57	Slight-moderate
40	F. oxysporum	91	—	7	9	Slight-moderate
42	F. solani f. pisi	96	—	31	40	Slight-moderate
44	F. solani f. pisi	78	—	9	22	Slight
46	F. solani f. pisi	47	—	47	47	Severe
47	F. solani f. pisi	98	2	6	37	Moderate-severe
49	F. solani f. pisi	20	—	20	20	Severe ; leaf curling
50	F. equiseti	94	1	4	13	Very slight
52	F. solani f. pisi	96	2	30	67	Severe
59	Mucor sp.	99	—	2	13	Slight
61	F. solani f. pisi	97	—	42	52	Severe
75	Phoma conidiogena	89	1	80	89	Severe ; stunting
76	Phoma conidiogena	21	22	9	20	Severe ; stunting
77	Phoma conidiogena	66	—	66	66	Severe ; stunting
80	F. solani f. pisi	71	2	18	41	Moderate
84	F. solani f. pisi	99	—	60	88	Moderate
88	F. solani f. pisi	99	—	8	75	Moderate
89	F. equiseti	100	1	2	17	Very slight
91	F. solani f. pisi	79	—	12	27	Slight-moderate
93	F. solani f. pisi	82	—	68	73	Moderate-severe
95	F. oxysporum	86	—	70	81	Severe
95A*	F. oxysporum	91	—	58	71	Moderate-severe
95B	F. oxysporum	95	—	66	79	Moderate-severe
95C	F. oxysporum	70	—	70	70	Severe
98	F. solani f. pisi.	74	—	69	72	Severe
102	F. solani f. pisi	95	—	20	42	Moderate-slight
105	Alternaria sp.	100	—	1	16	Slight
106	Phoma conidiogena	95	—	52	95	Severe
115	Sclerotinia sp.	0	—	—	—	Damping-off

*95B and 95C refer to single-spore cultures and 95A to a reisolate of 95.

Fig. 3—Effect of Culture No. 49 *(Fusarium solani* f. *pisi)* on peas. Note the dwarfing of the plants and the interveinal chlorosis and upward curling of the leaves. See Fig. 2 for relative size of such plants as compared to the controls of the same age.

plex. The organism causes severe damping-off of seedlings; the older survivors are stunted, showing black lesions on stems, roots, and cotyledons.

Other isolates obtained included *Fusarium oxysporum, Fusarium equiseti,* and species of *Verticillium, Alternaria, Rhizopus, Trichoderma, Penicillium, Mucor,* and various bacteria.

CONTROL EXPERIMENTS

Repeated experiments have been made in different parts of the world on the control of damping-off by seed treatment, and a fair degree of success has resulted. Of the fungicides tested, Semesan, New Improved Ceresan, Yellow Cuprocide, Red Cuprocide, zinc oxide, and, more recently, Spergon and Arasan have given a reasonable amount of control of damping-off in different localities and under various environmental conditions. The literature on this phase of the problem is voluminous and therefore will not be reviewed further than mentioning the chemicals used.

In initiating the experiments in Washington it was recognized that much work had been done on vegetable-seed treatments by workers in various parts of the country. There was much to be learned, however, concerning the efficacy of the several chemical seed treatments under Washington conditions. Local conditions demand special attention because procedures and materials satisfactory in one area are not necessarily completely effective or dependable in another. Studies of the relation of seed treatment to the seed-decay problem and the effects of other factors such as seed-coat injury, vitality and age of seed, and dates and depths of planting were needed. During the course of these investigations, other pertinent data such as effect of seed treatment on treated stored seed, and residual effect of fungicides, minimum effective dosages, and compatibility of seed treatment with legume bacteria were studied.

Control by Seed Treatment

SURVEY OF AVAILABLE SEED-TREATING MATERIALS

An exhaustive survey of available seed-treating materials was made in the hope of obtaining an ideal seed-treatment material for peas under Washington conditions. These chemicals were kindly donated by the various manufacturers to determine their worth. For this service the writer is deeply grateful. The testing of many chemical compounds was also conducted with the express purpose of finding new seed-treating fungicides to replace some of the old ones which became somewhat scarce during the second World War since they contained critical materials such as copper and mercury. Since these materials were obtained from 1942 to 1945, inclusive, no one experiment could include an evaluation of all the chemicals at the same time.

The seeds used in this study were treated in the usual way. In using liquid disinfectants, seeds were placed in a wire screen and submerged in the solution for one minute, removed from solution, and spread out to dry without rinsing. When using the seed treatment in dry form, the dust was added to seed contained in a glass jar or small rotary drum, depending on the amount of seed to be treated at one time. The seed was then mixed well to get the dust uniformly distributed over the seed surface. Plantings of the treated seed were usually made the same or following day.

In making the preliminary field (1942) and greenhouse tests (1943), 165 separate treatments were used. These were replicated twice in the field. The treatments were of two types: dry and liquid. In the dry form each compound was applied to 100 seeds of each germination class (Alaska and Green Giant) at the rate of 0.06 per cent (½ ounce per bushel), 0.25 per cent (2 ounces per bushel), and 0.50 per cent (4 ounces per bushel). Thus a rather wide range of dosages was obtained, from one fourth to twice the recommended rates. The liquid fungicides were used in a series of treatments parallel to those in which the dry compounds were used. The fungicides were put in suspension by means of addition of Penetrol or casein in varying amounts ranging from 0.125 to 0.50 per cent. The pea seed was soaked for one minute, allowed to dry, and planted a few days later.

Plantings were made in a random fashion and adequate check rows were provided. After sufficient growth had occurred, readings were taken and large numbers of individual plants were examined. From the data obtained, preliminary evaluations were made of the several treatments (Table 2).

The results in Table 2 indicate that several new promising seed protectants are being produced which appear to be as effective as the older treating materials. Chief among these newer materials are the Dubay organic sulphurs. The data also show that chemicals applied in liquid form, such as Dubay 1205 FF or Semesan in combination with casein or Penetrol, have potentialities. Spergon and New Improved Ceresan in liquid form gave negligible protection.

During the course of investigations a total of 32 compounds in dust form and 15 in combination with casein or Penetrol in liquid form were tested. Since a single table to show their effect on peas would not be feasible, it was considered advisable to list the compounds that were discarded and reasons for doing so. Of these, 21 in dust form and 11 in liquid form were eliminated (Table 3).

Considered as showing promise and therefore meriting further tests were Spergon, Semesan, Yellow Cuprocide, Arasan, Dubay 1205 FF, Dowicide B, Dowicide 5, Code No. 53-501-62 in dry form, Dubay 1205 FF + casein, Dubay 1205 FF + Penetrol, Semesan + casein, and Semesan + Penetrol.

The minimum effective amount of seed-treating material required

Table 2.—Emergence of peas treated with chemicals to determine their value as seed protectants.

Treatment	Dosage by Weight	D616J[1] Green-house	D616J[1] Field	D613JRR Green-house	D613JRR Field	A650JRR Green-house	A650JRR Field	D611JW Green-house	D611JW Field	D640JRR Green-house	D640JRR Field
	%	%	%	%	%	%	%	%	%	%	%
Untreated check	none	48	73	7	36	9	41	11	35	4	12
Spergon	0.25	79	84	27	75	52	74	31	83	4	52
Spergon + casein	0.25	40	—	12	—	83	—	13	—	22	—
New Improved Ceresan	0.025	59	75	23	73	14	57	33	81	0	48
New Improved Ceresan + casein	0.25	52	—	15	—	13	—	14	—	6	—
Semesan	0.25	87	93	29	75	46	65	64	62	24	42
Semesan + Penetrol	0.50	92	73	—	40	32	25	26	37	14	22
Semesan + casein	0.50	82	86	20	76	27	63	—	68	11	56
Yellow Cuprocide	0.25	88	82	35	54	50	38	60	36	34	24
Dubay 1205 FF[2]	0.25	89	77	45	76	51	66	31	69	12	44
Dubay 1205 FF + casein	0.25	57	62	6	42	30	39	10	51	9	24
Dubay 1205 FF + Penetrol	0.25	77	86	37	47	30	36	45	51	13	39
Dubay 1205 U	0.25	80	—	—	—	46	—	58	—	16	—
Dubay 1205 AK[3]	0.125	95	—	71	—	63	—	—	—	—	—
Dubay 1242 CC	0.25	34	—	13	—	40	—	11	—	—	—
Ceresan	0.25	—	69	6	34	—	49	8	66	—	27
Ceresan + casein	0.25	—	—	—	—	—	—	—	26	—	—
Ceresan + casein	0.50	—	61	—	—	—	35	—	29	—	27
Ceresan + Penetrol	0.50	—	70	—	—	—	38	—	32	—	20
$CuCO_3$	0.25	45	77	—	69	—	67	—	69	0	29
$CuCO_3$ + casein	0.50	—	72	—	58	—	48	—	45	—	16
$CuCO_3$ + Penetrol	0.50	—	58	—	38	—	37	—	34	—	28
Calomel + casein	0.50	18	67	0	29	0	26	1	34	0	14
Calomel + Penetrol	0.50	26	76	1	34	2	57	2	38	0	16
$HgCl_2$ + casein	0.50	22	81	1	32	4	46	5	37	2	21
$HgCl_2$ + Penetrol	0.50	—	68	2	21	—	34	3	28	—	19
Calcium cyanamide	0.0625	—	74	—	40	—	38	—	32	—	14
Calcium cyanamide	0.25	—	75	—	42	—	43	—	29	—	17

[1] Seed lot numbers.
[2] Marketed as Thiosan.
[3] Marketed as Arasan.

Table 3.—Seed-treatment compounds eliminated from further experimentation by preliminary tests.

Compound	Reason for elimination
Red Cuprocide	Yellow Cuprocide better: finer and more adhesive
Copper carbonate	Requires graphite
Lacco Copro 50	Requires graphite
Micronized copper	Requires graphite and is toxic to man
Thiosan	Other organic Dubay sulphurs equally effective and more adhesive
2% Ceresan	Ineffective
New Improved Ceresan	Very toxic to man and phytotoxic under certain conditions
Calcium cyanamide	Ineffective
Micronized sulphur	Ineffective and at times decreases stands
Dubay 1205 FF	Other Dubay compounds; less dusty, and is toxic to man
Sulfanilic acid	Ineffective
Fermate	Requires graphite; poor adhering qualities
Dubay 1205 U	Requires graphite
Dubay 1242 CC	Ineffective; requires graphite
Dowicide B	Toxic to man
Dowicide 4	Ineffective and toxic to man
Dowicide 7	Ineffective and toxic to man
Dowicide 8	Toxic to man
Dowicide F	Ineffective and toxic to man
Dowicide G	Ineffective and toxic to man
Code No. 240	Ineffective
Code No. 582	Ineffective
Code No. 649	Ineffective
DDT	Poor adherency, requires graphite, and ineffective
Ethyl mercury p-toluene sulfonanilide	Toxic to man
Calomel + casein	Ineffective
Calomel + Penetrol	Ineffective
Mercuric chloride + casein	Ineffective
Mercuric chloride + Penetrol	Ineffective
Spergon + casein	Ineffective
Spergon + Penetrol	Ineffective
New Improved Ceresan + casein	Ineffective
New Improved Ceresan + Penetrol	Ineffective
Micronized sulphur + lime	Ineffective
Dowicide B + casein	Ineffective
Dowicide G + casein	Ineffective

was ascertained by using different dosages ranging from 0.625 (0.5 ounces per bushel) to 0.25 (2.2 ounces per bushel) per cent by weight in field trials planted on April 27, 1943, and May 9, 1944. The Green Giant variety was used.[4] Materials tested included Spergon, Dubay 1205 FF, Dubay 1205 AK, Improved Ceresan, Semesan, Dowicide 5, Dowicide 8, Yellow Cuprocide, Fermate, and Code No. 53-501-62. Results were based on three replications of 100 seeds each; since results for 1944 and 1943 were similar, only one year's data are recorded (Table 4).

Table 4.—Minimum amount of various fungicides required for adequate protection of three lots of Green Giant pea seed planted on College Farm, Pullman, Washington, 1943.

		Average emergence[1]		
	Dosage by weight	Lot D601K-2	Lot D629JRR	Lot D615J
	%	%	%	%
Control	none	44	28	23
Spergon	0.125	67	42	46
	0.150	71	41	43
	0.175	68	49	50
	0.200	71	51	52
Arasan	0.0625	52	30	37
	0.1250	58	38	42
	0.1875	66	47	51
	0.2500	68	53	50
Dubay 1205 FF	0.0625	74	37	41
	0.1250	61	41	41
	0.1875	65	52	51
	0.2500	68	53	50
Dubay 1205 AK	0.0625	55	38	39
	0.1250	62	39	45
	0.1875	67	52	47
	0.2500	73	53	53
New Improved Ceresan	0.1250	73	67	58
Yellow Cuprocide	0.1250	54	43	47
	0.1875	63	55	57
Fermate	0.0625	65	48	47
	0.1250	63	49	48
	0.1875	69	48	49
Code No. 53-501-62	0.2500	74	65	62

[1] Based on two replications of 100 seeds each.

[4] This variety is a selection made by the Breeding Department of the Blue Mountain Canneries, Inc. Its parentage has not been revealed although it resembles the Perfection variety.

From the 1942 field trials as recorded in Table 4, Spergon applied at 0.125 per cent (1.1 ounces per bushel) is for all practical purposes as effective as 0.2 per cent (1.0 ounces), as was verified in the 1944 field trials. The adequacy of protection using 0.125 per cent (1.1 ounces per bushel) is true for one-year-old seed (D601K-2) and two-year-old seed (D629JRR and D615J). The organic sulphur compounds, namely, Arasan, Dubay 1205 AK, and Dubay 1205 FF, gave substantial increases at the rate of 0.0625 per cent (0.5 ounces per bushel), though 0.1875 per cent (1.6 ounces) would be a better dosage rate. Similarly, Semesan at 0.125 per cent (1.1 ounces) is as effective as 0.250 per cent (2.2 ounces), and Fermate gave fairly good protection at 0.0625 per cent (0.5 ounce); so did Yellow Cuprocide at 0.1875 per cent (1.6 ounces) and Code No. 53-501-62 at 0.250 per cent (2.2 ounces) (Table 4). In the 1944 tests of New Improved Ceresan and Dowicide No. 5, no apparent difference in emergence was obtained by using different dosages of these fungicides. Applications of Arasan at the rate of 0.125 per cent (1.1 ounces) and Semesan at 0.1875 per cent (1.6 ounces) were as effective in either case as 0.250 per cent (2.2 ounces). A relatively poor lot of seed was used in the 1944 field trials in order to detect any difference that may arise due to small changes in rates of application of seed-treating materials.

SEED-COAT INJURY AS A FACTOR AFFECTING THE VALUE OF SEED TREATMENT

Amount of Broken Hulls in Seed Samples

Determinations made through the use of a binocular microscope revealed a high percentage of injured hulls of certain seed lots, ranging in size from microscopic to those visible with the naked eye. This is a tiresome procedure and the use of a dye to bring out these breaks in the seed suggested itself. Various dyes were selected at random but with little success. Finally the use of iodine suggested itself because the cotyledons of peas are of a starchy nature. The seed was dipped in the iodine for one minute (one gram of iodine and one-half gram of potassium iodide in 100 ml. of water). Dark-blue areas appeared at the sites of seed-coat injury. To shorten the dipping period a surface depressant-like soap was tried with good success. Seed-coat breaks showed up as water-soaked areas. Plain water would thus act as a medium in determining seed-hull injury. A comparison of iodine and water baths proved them to be equally good (Table 5).

It will be noticed that in many seed samples a considerable proportion of the seeds have cracked testas. The number of injured seeds varied from 2 to over 60 per cent of the total and the cracks ranged from microscopic to those visible to the unaided eye. Evidently macroscopic examination of dry seeds does not give a true picture, for by means of a water dip a larger number of seeds with broken seed coats were found to be present.

Table 5.—Percentage of seed in samples of Green Giant peas with broken seed coats as determined by three methods.

Seed lot	Method of determination		
	Macroscopic	Water bath	Iodine bath[1]
	%	%	%
D601K-2	5.6	46.0	43.0
D623K	2.1	12.0	13.0
D629K	0.6	11.0	6.0
D629JRR	3.1	36.0	23.0
D615J	3.5	37.0	29.0
D606K	1.1	9.0	—
D611K	8.7	49.0	—
D609K	15.7	63.0	—
F673M	2.1	10.9	—
F674M	2.5	7.2	—
F672M	0.7	6.3	—
F675M	2.8	10.0	—
E660M	2.5	24.6	—
E661M	2.2	23.1	—
E662M	4.7	18.0	—
E663M	7.1	28.8	—
D602L	0.6	8.5	—
D646M	0.3	2.1	—
D600M	1.4	10.1	—
D601M	0.4	2.6	—
D602M	2.6	8.2	—
D609M	1.6	4.7	—
D610M	1.8	7.1	—
D614M	1.2	4.4	—
D640M	0.5	7.6	—
D641M	1.5	5.5	—
D642M	0.5	3.4	—
B650M	6.5	20.6	—
F670M	1.8	4.7	—
F671M	2.3	8.3	—

[1] After testing the first five lots it was found that the results between the water and iodine methods did not vary significantly. The remaining lots which were received a few months later were not run through the iodine bath.

Table 6.—Comparison of methods in determining the amount of cracked seed in samples of two pea varieties.

Seed description (var. and lot no.)	Percentage of cracked seed as determined by	
	Macroscopic examination	Iodine bath
	%	%
No. 2 Green Giant—D605K	4.2	25.0
No. 2 Alaska—C257K	4.2	6.0

To further test the practicability of the iodine bath method, seed lots of Alaska as well as Green Giant varieties were obtained with high percentages of broken testas (as ascertained by macroscopic examination by technicians of the Blue Mountain Company, Inc.). Results by the use of the iodine bath showed differences from macroscopic determinations (Table 6).

The results for the Alaska peas seem to compare fairly well, but such is not the case for the Green Giant peas. The fact that the seed may be wrinkled, as in the Green Giant variety, may make it difficult to see breaks; in the smooth peas (Alaska) this difficulty is not encountered to such an extent. The data show that iodine brings out the minor cracks which are not visible to the naked eye.

Relationship of Seed-Coat Injury to Disease Incidence

There is evidence that there may be a direct correlation between the seed-coat injury and susceptibility to damping-off organisms. It has been shown that bacteria previously isolated from inside the seed reduced germination of peas with chipped coats but did not affect germination of those with unbroken coats. Hulbert *et al* (5) found that germination was decreased in direct proportion to the severity of seed-coat injury.

An attempt was made to ascertain the relationship of disease incidence and seed-coat injury under Washington conditions. There seems to be an indirect relationship between seed-coat injury and percentage emergence in the greenhouse plantings; the field tests did not bring out this correlation so markedly, although the seed with injured testas produced the smaller stand. This difference in the results is apparently due to more adverse conditions in the greenhouse.

In the following year, 1944, field experiments were repeated, including a smooth-seeded variety. The results are shown in Table 7.

Table 7.—Effect of treatment and seed-coat injury of smooth and wrinkled peas under field conditions, 1944.

Variety	Seed-coat condition	Seed treatment	Percentage emergence
Green Giant	Cracked	Untreated	68
	Cracked	Spergon	96
	Uncracked	Untreated	92
	Uncracked	Spergon	96
Alaska	Cracked	Untreated	72
	Cracked	Spergon	92
	Uncracked	Untreated	96
	Uncracked	Spergon	92

To further determine the value of the seed coat as a protective covering, the relationship of severity of seed-coat injury to emergence was studied. The three types of injury were studied: (1) shelled (testas removed); (2) unshelled, broken testas; (3) unshelled, uncracked testas. Parallel studies of untreated and Spergon-treated seed were run in this experiment, using both Alaska and Green Giant pea varieties. Complete loss of stand of both varieties resulted when shelled, untreated seed was planted in non-sterilized soil. For the Green Giant variety, a 12-per-cent stand resulted for the cracked, untreated and uncracked, untreated seed; but in the Alaska variety the last type produced approximately three times better stands. This indicates a degree of resistance in Alaska peas. In the case of seed treatment with Spergon, there was a positive correlation between severity of seed-coat injury and the decrease in stand. In sterilized soil almost perfect stands resulted regardless of the degree of seed-coat injury, proving that such injury did not harm the cotyledons.

Comparison of Machine- and Hand-Threshed Seed

One source of cracking of seed has been shown to result from drilling and threshing the seed. The possibility was considered that threshing may be involved under local conditions, as shown in Table 8.

Apparently there was some difference in the amount of seed cracking due to type of threshing method employed. Machine threshing may be one factor in causing seed-coat injury, as indicated by results obtained and recorded in Table 8. There is a possibility that operating the machine at slower cylinder speed may decrease the amount of cracks, as has been shown for flax by Schuster *et al* (13). The data in Table 8 would indicate that there also is some injury due to natural causes.

The Value of Seed Treatment in Reducing Losses Due to Seed-Coat Injury

The use of seed treatment as a means of overcoming the detrimental effect of seed-coat injury was another method attempted. Cracked seed of Green Giant peas treated with Spergon and Arasan showed an increase in stand of 29 to 56 per cent over the untreated check in 1943 field trials. In the following year the Alaska or smooth peas were included in the test (Table 7). Increases in stand of Alaska

Table 8.—Comparison of extent of seed-coat cracking and percentage emergence resulting from hand- and machine-threshed seed, 1944.

Type of threshing	Percentage cracking	Percentage emergence
	%	%
Hand	3	92
Machine	19	85

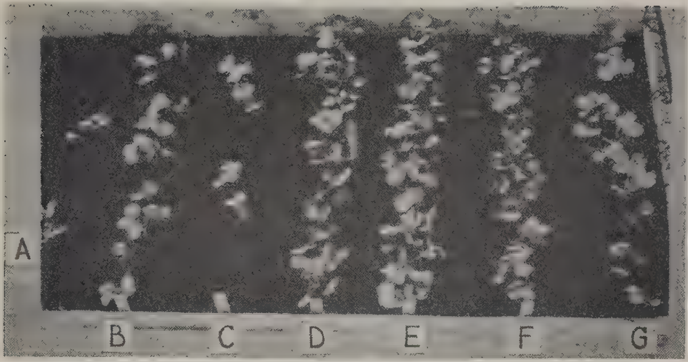

Fig. 4—Effect of seed treatment on emergence of peas with broken and unbroken seed coats. Left to right, *Row A.* Cracked, untreated seed sown. *Row B.* Cracked, Arasan *Row C.* Cracked, untreated. *Row D.* Uncracked, Spergon. *Row E.* Uncracked, Arasan. *Row F.* Uncracked, untreated. *Row G.* Border row.

peas of 28 per cent were obtained through the use of Spergon. For the wrinkled peas, a 40-per-cent increase in stand resulted from treatment of seed with broken testas. The results are in conformance with 1943 and 1944 greenhouse test (Fig. 4).

Effect of Seed Treatment on Cracked and Uncracked Seed in Storage

From one seed lot, D623K, which was used in the storage experiment, cracked and uncracked seed, treated and untreated, were selected and planted 30 months after treatment. Twenty-five seed of each combination were planted per 6-inch pot of steam-sterilized soil in the greenhouse. These were planted in duplicate and results are recorded in Table 9.

Of the eight treatments used in the storage experiment, only New Improved Ceresan seems to have injured the seed with broken testas, as shown in Table 9 (Fig. 5). Semesan also stunted the plants, though the stand was not decreased in comparison with the untreated check. It is interesting to note that both these fungicides contain mercury as the toxic principle. Micronized Sulphur, which in practically all the storage experiments seemed to give stands less than the untreated checks, did not produce any injury when the seed was sown in sterilized soil (Table 9). Why apparent injury should result when the seeds were sown in normal soil in the greenhouse and field is without explanation.

Further observation shows that seed with broken testas did not all produce seedlings even in sterilized soil. This may account in part for the differences obtained in the laboratory and field plantings of the several lots used in the storage experiment.

Fig. 5—Fungicide injury to peas grown from seed with broken seed coats, treated with New Improved Ceresan and stored for a period of 30 months. *A*. Uncracked, untreated seed. *B*. Cracked, untreated. *C*. Uncracked, New Improved Ceresan. *D*. Cracked, New Improved Ceresan. Seed sown in sterilized soil.

Table 9.—Effect of seed treatment on cracked and uncracked seed coats of peas stored for 30 months.

Treatment	Condition of seed coat	Average emergence[1]
Untreated	Cracked	19
	Uncracked	23
Dubay 1205AK	Cracked	16
	Uncracked	24
New Improved Ceresan	Cracked	10
	Uncracked	23
Semesan	Cracked	18
	Uncracked	20
Dubay 1205FF	Cracked	19
	Uncracked	23
Spergon	Cracked	17
	Uncracked	22
Micronized copper	Cracked	16
	Uncracked	23
Micronized sulphur	Cracked	20
	Uncracked	23
Yellow Cuprocide	Cracked	22
	Uncracked	23

[1] Two replicates of twenty-five seeds each.

ENVIRONMENTAL FACTORS INFLUENCING THE EFFECTIVENESS OF SEED TREATMENT

Time of Watering

It has been shown elsewhere (*2*, *8*) that the amount of soil moisture has a striking effect upon emergence of seed. With this in mind, some consideration was given to the effect of time of watering on emergence of peas in the greenhouse to simulate the effect of rains before or after planting treated seed in the field. The seed used was of the same lot but with different treatments and soil moisture, as shown in Table 10.

Table 10.—Effect of time of application of water on effectiveness of seed treatment of Green Giant peas in the greenhouse trials of 1942-1943.

Seed Lot No.	Treatment (dosage)	Emergence: Watered before planting	Emergence: Watered immediately after planting
		%	%
D623K	Untreated check	8	6
D629K	Untreated check	3	2
D623K	Spergon (0.2%)	68	58
D629K	Spergon (0.2%)	66	52
D623K	Arasan (0.2%)	80	68
D629K	Arasan (0.2%)	73	67
D623K	Semesan (0.33%)	77	75
D629K	Semesan (0.33%)	80	78
D623K	New Improved Ceresan (0.125%)	92	72
D629K	New Improved Ceresan (0.125%)	72	64
D623K	Dubay 1205 AK (0.25%)	84	86
D629K	Dubay 1205 AK (0.25%)	70	76
D629K	Dubay 1205 FF (0.2%)	81	73

The data would indicate that dissipation of protectants may occur if the soil is watered immediately after planting. Spergon, Arasan, New Improved Ceresan, and Dubay 1205 FF are less effective if water is applied immediately after planting; on the other hand, Dubay 1205 AK and Semesan apparently were not affected. Jones (8) found that the value of Semesan as a protectant was decreased considerably if the soil was watered immediately after planting, while the present results showed but a slight decrease. Under dry soil conditions it was observed in greenhouse tests that protectants such as New Improved Ceresan caused root injury, preventing the proper formation of secondary roots. Stunting of the primary roots under dry conditions due to 2% Ceresan was noted by some investigators. Undoubtedly, moisture conditions are one of the factors responsible for such disease results obtained in different localities.

Table 11.—Analysis of variance of emergence in dates of planting and seed-treatment trial with wrinkled peas at two locations in Washington, 1944.

Variation due to	Degrees of freedom	Mean square Pullman	Dayton
Blocks	2	78.5	440.0
Date of planting	3	431.3**	5,447.0**
Error a	6	28.7	355.0
Main plots	11		
Seed treatment	6	728.0**	112.7
Date of planting seed treatment	18	71.4**	66.9
Error b	48	14.4	132.3
Total	83		

**Highly significant.

Effect of Date of Planting on Seed Treatment

Since soil moisture and other environmental conditions vary as the season progresses, wrinkled peas were planted at different dates at Pullman and Dayton, Washington (Table 11). An experiment using a split-plot technique was designed with four different dates of planting and seven seed treatments. Dates of planting were made one week apart: April 11, April 18, April 25, and May 2, 1944, at Pullman and on April 16, April 22, April 29, and May 6, 1944, at Dayton, Washington. Spergon, Arasan, Semesan, Dowicide 5, and Dowicide 8 were applied at the rate of two ounces per bushel, and New Improved Ceresan at the rate of one ounce per bushel.

From these trials it is evident that there were significant differences in emergence from seed sown at different dates at two locations. At Pullman the third planting resulted in a significantly poorer stand than the first and second, and the fourth planting produced a significantly greater stand than did the first three seeding dates. At Dayton the third date of planting was also significantly lower than the first and second plantings. Furthermore, the fourth planting produced the poorest stand, being significantly less than the first and second dates but not the third sowing date. Apparently weather conditions differed between the two localities during the first part of May, 1944. This is in contrast to the findings of Baylis *et al* (*2*), who found that emergence of untreated peas is better at the later sowing date, especially in heavy soils. This fact is apparent only in the fourth planting at Pullman, but certainly was not the case at Dayton.

Insofar as seed treatment is concerned, highly significant differences were found at Pullman but not at Dayton. At Pullman the six treatments resulted in highly significant increases in stand over the untreated checks. Spergon and Dowicide 5 are significantly better than Semesan, Arasan, Dowicide 8, and New Improved Ceresan. Seed treatment was most effective during the earlier planting at Pullman

Table 12.—Emergence of wrinkled peas planted on May 12, 1944, at different depths, Pullman, Washington.

Treatment	Depth of planting	Per cent of emergence	
		6/9/44	7/5/44
		%	%
Untreated check	1″	11	40
Spergon	1″	15	69
Untreated check	3″	48	63
Spergon	3″	56	79

with increases in stand (using Spergon as an example) of 20, 55, 71, and 6 per cent for the four respective dates of seeding. This confirms the fact that seed treatment does the most good under adverse growing conditions.

Apparently, as the data indicate, locations have a decided influence upon the effect of planting dates. The average emergence for dates of seeding was greater at Pullman for the first and second plantings but less for the third and fourth plantings as compared with those made at Dayton. Furthermore, the Pullman experiment also differed in that seed treatment and interaction of dates with seed treatment were highly significant. Environmental factors obviously must play an important role. Since the *Fusaria*, which are the most important soil-borne disease organisms, are generally most pathogenic under warmer conditions, it may be assumed that this factor may account for the difference obtained.

Effect of Depth of Planting on Emergence and Seed Treatment

It was surmised that seed planted deeper would be in greater danger of rotting before emergence than seed planted at a shallow depth. To test this possibility an experiment was devised, planting seed of Green Giant peas at different depths in the field. The results are shown in Table 12.

As shown in Table 12, the seed planted at a depth of three inches emerged sooner than seed planted one inch deep. This was due to the fact that the upper layer of soil was dry. The seed planted one inch deep remained longer in the soil before emerging; in fact, seedlings did not begin coming through the soil until about a month after planting, as indicated in Table 12. This would account for the poorer stand of untreated seed planted one inch deep as compared to seed planted three inches deep. There was a greater response due to treatment of seed planted an inch deep in comparison with seed sown three inches deep. The increase of treated over untreated seed was 27 and 45 per cent for seed planted three inches and one inch deep, respectively. The reason for this, obviously, was that seed remaining in the soil for a longer period of time had to cope with soil-borne organisms for a greater length of time.

Table 13.—Analysis of variance of emergence and yield of Alaska peas of experiment on date of seeding × depth of seeding × seed treatment at Pullman, Washington, 1944

Source of variation	Degrees of freedom	Mean square	
		Emergence	Yield
Blocks	2	21.1	319.1
Dates	3	1193.1**	1109.6
Error (1)	6	15.3	3694.2
Seed treatments	2	249.9*	837.9
Dates × treatments	6	239.9*	1385.9
Error (2)	16	63.2	955.2
Depths	1	156.1*	11375.4**
Depths × treatments	2	67.0	464.6
Depths × dates	3	154.1*	2854.0**
Depths × treatments × dates	6	6.5	539.4
Error (3)	24	35.6	448.3
Total	71		

*Significant.
**Highly significant.

Interaction of Date and Depth of Seeding on Emergence and Yield

A study of the effect of different dates of seeding and different depths of planting on emergence and yield of smooth or Alaska peas was attempted. The experimental design was that of a split plot. The four dates of planting were made at nine-day intervals beginning April 10, 1944. The two depths of seeding employed were two and four inches. Arasan and Spergon were applied at two ounces per bushel. An analysis of variance of emergence and yield data for the experiment is recorded in Table 13.

In the emergence data it is seen that there are highly significant differences between dates of planting, and significant differences for seed treatments, depths of planting, dates x seed treatments, and depths x dates (Table 13). There was decidedly less emergence in the earliest planting. The third planting gave a poorer stand than did the second and fourth planting. Of the seed treatments, Spergon and Arasan were about equally effective, considering all dates of planting, being decidedly better than the untreated check in the first two plantings, but not in the third and fourth plantings. Increases in stand due to seed treatment of 24, 8, 6, and 2 per cent, respectively, were obtained for the four dates of seeding. This again substantiates the general belief that seed treatment is most effective during adverse growing conditions. Emergence from peas sown four inches deep was significantly better than from seed sown two inches deep. But seed planted two inches deep gave a slightly better stand during the first

planting. The converse was true in the last three plantings. These data on depths of planting are quite similar to the experiment with wrinkled peas.

Insofar as yield data are concerned, only depth of seeding and depths x dates of seeding gave significant F values. The yield from seed placed four inches deep was greater than from seed sown two inches deep. In the first planting yield was slightly in favor of the two-inch depth, but the results were reversed in the second and particularly in the third and fourth seeding dates.

Effect of Storage on Vitality of Treated Seed and Stability of Fungicides.

Large samples of seed were treated with several chemical compounds, and stored; periodic germination tests and yield data were obtained to determine the effect of the treatment and subsequent storage over a period of from one to three years. Sixty-pound samples of each lot were treated on October 31, 1942, with the following materials: Spergon, New Improved Ceresan, Semesan, Dubay 1205 AK, Dubay 1205 FF, Yellow Cuprocide, Micronized Copper, and Micronized Sulphur. Dosage used was two ounces per bushel for all the chemicals except New Improved Ceresan, which was applied at the rate of one ounce per bushel. The seed was stored in cotton bags in the warehouse of the Blue Mountain Canneries, Inc., Dayton, Washington. The temperature of the room was regulated by a thermostat at 50-55° F. and the relative humidity was kept as near as possible at 37 per cent. Five different lots of the Green Giant variety treated were as follows: Lot. No. D601K-2 (1942 seed), D623K (1942 seed), D629K (1942 seed), D629JRR (1941 seed), and D615J (1941 seed). An untreated sample of each lot of seed was set aside as a control in the germination tests. Laboratory germination tests were run at the time of harvest; on December 12, 1942; October 25, 1944; and March 15, 1945. Moisture content of the five lots of untreated seed was determined at the time of harvest, on January 28, 1944, and on January 27, 1945. Using a Brown-Duval moisture tester, the procedure was as follows: 100 grams of seed and 150 grams of oil were added to a Pyrex distillation flask which was heated to 175° F. and then cooled to 160° F.; the percentage of moisture was read directly from the graduated cylinder. The amount of seed-coat cracks in the five lots was ascertained on October 9, 1945, using the water dip method. The treated, stored seed was planted in the greenhouse on March 26, 1943; November 9, 1943; and January 7, 1944. The first field plantings were made in April, 1943, at Dayton and Pullman, Washington. The second was made on April 16, 1944, at Dayton and May 6, 1944, at Pullman. The third plantings at Dayton and Pullman, Washington, were made on April 15, 1945, and May 3, 1945, respectively. The plantings in the greenhouse were made in a random fashion, and in the field a split-

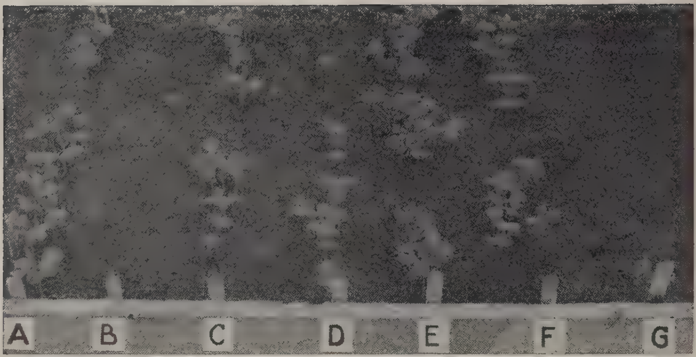

Fig. 6—Emergence of peas in the greenhouse from 1941 seed treated and stored for 26 months. *A*. Dubay 1205 FF; *B*. Micronized sulphur; *C*. Semesan; *D*. New Improved Ceresan; *E*. Dubay 1205 AK; *F*. Micronized copper; *G*. untreated.

Table 14.—Periodic germination tests in the laboratory of seed lots of peas.

Seed lot	Length of storage period in days				
	0	42	725	860	Average
D601K-2	93.0	88.0	91.5	91.50	91.0
D623K	84.0	—	86.0	91.25	87.1
D629K	75.0	—	86.0	88.0	83.0
D629JRR	86.0	90.0	86.0	86.0	87.0
D615J	78.0	89.0	79.5	71.25	79.4

plot type of experimental design was followed. Besides determining the stability and phytotoxic properties of fungicides in these tests, information was sought on the effect of storage on the longevity and vitality of the particular variety of peas.

The results of periodic laboratory germination tests of the five lots of Green Giant are recorded in Table 14.

In addition to these laboratory tests, periodic tests were conducted in the greenhouse and field for one to three years. There were highly significant increases in stand in the field due to seed treatment of 1941 seed lots, D629JRR and D615J, after 6, 19, and 30 months of storage (Table 15). Very similar results were found for the 1942 pea seed for the same period of storage in the field planting at Dayton, Washington, with the six- and nineteen-month periods just short of being significant. In the greenhouse plantings, increases in stand from 67 to 1,000 per cent over the untreated check resulted from 1941 seed and 17 to 240 per cent for the 1942 seed after 5, 12, and 26 months of storage. Micronized Sulphur decreased stands in 85 per cent of the cases (Table 21 and Fig. 6).

The eight seed treatments in this same storage test showed significant increases in emergence of 1941 seed. This was obtained through the use of Spergon, Semesan, Dubay 1205 FF, Dubay 1205 AK, and Yellow Cuprocide for all three storage periods and two locations. Of these six possible combinations of storage time and place of planting, New Improved Ceresan was not significant in half the cases, and Micronized copper was of no value as a seed treatment in any of the plantings of 1941 seed.

For the 1942 seed, no single seed treatment gave a significant increase in stand in all six possible combinations. New Improved Ceresan was significant five times out of six; Spergon, Semesan, and Dubay 1205 AK, four times; Yellow Cuprocide, three times; Dubay 1205 FF, two times; and Micronized copper, once. Again Micronized Sulphur was of little value; in fact, significant decreases resulted in two cases.

Increases in yield were not obtained as frequently as increased emergence. At Pullman, 1941 seed after six months of storage showed highly significant increases; the yield of seed stored for 30 months and sown at Dayton just barely reached significance. For the 1942 seed, yield was significantly increased at Dayton from seed stored for 30 months and was just short of significance at Pullman for seed stored six months.

Of the eight treatments tested, significant increases in yield resulted from seven of them with the 1941 seed stored six months and sown at Pullman. Micronized Sulphur caused a decrease in yield. For the 1942 seed, Spergon, Yellow Cuprocide, and Dubay 1205 FF produced significantly better yields at Dayton after 30 months of storage.

Seed lots of the same variety of peas resulted in differences in stand in this storage experiment. Seed lot D601K-2 was significantly inferior to D623K and D629K, which were equally good. The two 1941 lots, D629JRR and D615J, were not significantly different, with one possible exception. The 1942 lots, however, showed differences in yield in one case as did the two 1941 lots. The emergence data do not conform too closely with laboratory germination tests which indicate lot D601K-2 to be the better lot of the 1942 seed and D629JRR the better lot of the 1941 seed (Table 14). A partial explanation may be the higher percentage (46 per cent) of seed coat cracking in the D601K-2 lot compared to D623K and D629K with 11 and 12 per cent, respectively (Table 5).

Table 15.—Analysis of variance of emergence of two lots of 1941 pea seed treated in 1942, stored for six, nineteen, and thirty months and sown in the field at Dayton and Pullman, Washington.

		Mean square					
	Degrees of	6 months		19 months		30 months	
Variation due to	freedom	Dayton	Pullman	Dayton	Pullman	Dayton	Pullman
Blocks	2	3.50	168.5	269.5	11.25	85.0	69.5
Seed treatment	8	420.12**	1,209.0**	698.9**	352.5**	790.3**	694.0**
Error a	16	83.19	45.4	61.8	50.8	50.9	59.2
Main plots	26						
Seed lots	1	1.00	178.0**	21.0	116.0	66.0	16.0
S.T. × S.L.	8	37.13	76.5**	57.4	26.6	64.9*	93.5*
Error b	18	24.72	11.3	51.4	46.6	23.1	32.7
Total	53						

*Significant.

**Highly significant.

Table 16.—Analysis of variance of emergence in the field at Dayton and Pullman, Washington, of three lots of 1942 pea seed treated in 1942 and stored for six, nineteen, and thirty months.

		Mean square					
	Degrees of	6 months		19 months		30 months	
Variation due to	freedom	Dayton	Pullman	Dayton	Pullman	Dayton	Pullman
Blocks	2	58.5	269.5	437.5	112.5	302.5	120.5
Seed treatment	8	111.5[1]	1,159.4**	233.0[1]	352.4**	620.6**	251.9**
Error a	16	50.6	26.1	96.6	50.8	168.3	27.4
Main plots	26						
Seed lots	2	932.0**	3,143.5**	1,926.5**	166.0[1]	2,931.0**	1,494.5**
S.T. × S.L.	16	36.8[1]	132.3**	52.9	26.6	61.1	32.3*
Error b	36	21.0	44.9	50.0	46.6	54.5	16.0
Total	80						

[1]Just short of significance.

*Significant.

**Highly significant.

Table 17.—Analysis of variance of yield of peas grown in the field at Dayton and Pullman, Washington, of two lots of 1941 seed treated in 1942 and stored for six, nineteen, and thirty months.

Variation due to	Degrees of freedom	Mean square: 6 months Dayton	6 months Pullman	19 months Dayton[1]	19 months Pullman	30 months Dayton	30 months Pullman
Blocks	2	7.2	15.7		31.2	3.96	9.0
Seed treatment	8	8.1	144.4**		12.2	2.38[2]	2.0
Error a	16	5.2	9.3		19.5		3.8
Main plots	26						
Seed lots	1	0.8	66.2*		0.2	0.69	2.3
S.T. × S.L.	8	2.9	18.1		7.9	0.82	0.4
Error b	18	16.6	10.2		17.6		0.9
Total	53						

[1]Yield not taken.

[2]Just short of significance.

*Significant.

**Highly significant.

Table 18.—Analysis of variance of yield of peas of three lots of 1942 seed treated in 1942, stored for six, nineteen, and thirty months and grown in the field at Dayton and Pullman, Washington.

Variation due to	Degrees of freedom	Mean square: 6 months Dayton	6 months Pullman	19 months[1] Dayton	19 months[1] Pullman	30 months Dayton	30 months Pullman
Blocks	2	79.3	11.9			95.2	10.2
Seed treatment	8	2.6	32.0[2]			26.0*	14.0
Error a	16	2.7	15.8			8.1	15.1
Main plots	26						
Seed lots	2	2.0	81.9**			18.5	2.3
S.T. × S.L.	16	1.9	8.1[2]			7.9	3.0
Error b	36	1.8	4.6			9.8	1.6
Total	80						

[1] Yield data were not obtained for the 19-month period at Dayton; the Pullman data was not considered worth analyzing.

[2] Just short of significant.

*Significant.

**Highly significant.

Table 19.—Per cent of increase in emergence of treated seed over the untreated check of 1941 pea seed treated and stored for six, nineteen, and thirty months and sown in the field at two locations in Washington.

Seed treatment	6 months		19 months		30 months		Average
	Dayton	Pullman	Dayton	Pullman	Dayton	Pullman	increase
	%	%	%	%	%	%	%
Dubay 1205 FF	44	226	54	26	147	38	80
New Improved Ceresan	18	284	19	29	107	12	78
Semesan	41	317	43	33	217	18	93
Dubay 1205 AK	47	284	52	36	189	48	109
Spergon	44	317	61	57	175	49	117
Micronized copper	42	218	21	5	152	31	78
Micronized sulphur	10	16	–6	10	24	–13	7
Yellow Cuprocide	31	201	58	24	108	34	76

Table 20.—Per cent of increase in emergence of treated seed over untreated check of 1942 pea seed treated and stored for six, nineteen, and thirty months and sown in the field at two locations in Washington.

Seed treatment	6 months		19 months		30 months		Average
	Dayton	Pullman	Dayton	Pullman	Dayton	Pullman	increase
	%	%	%	%	%	%	%
Dubay 1205 FF	9	23	5	4	22	6	12
New Improved Ceresan	11	41	17	8	32	5	19
Semesan	10	33	11	0.7	35	5	16
Dubay 1205 AK	6	26	10	13	23	6	14
Spergon	10	28	8	3	24	4	13
Micronized copper	3	14	3	–4	16	–2	5
Micronized sulphur	0	–24	–9	–3	–10	–14	–10
Yellow Cuprocide	6	18	10	0.2	24	–0.5	10

Table 21.—Per cent of increase in emergence of treated seed over the untreated check of 1941 and 1942 pea seed treated and stored for five, twelve, and twenty-six months and planted in the greenhouse at Pullman, Washington.

Seed treatment	1941 seed			1942 seed		
	5 months	12 months	26 months	5 months	12 months	26 months
	%	%	%	%	%	%
Dubay 1205 FF	407	267	729	29	33	183
New Improved Ceresan	350	67	282	26	37	210
Semesan	321	222	835	32	30	200
Dubay 1205 AK	336	222	1009	35	30	240
Spergon	167	278	665	23	50	210
Micronized copper	321	311	830	17	26	143
Micronized sulphur	–71	122	–29	–46	–13	–50
Yellow Cuprocide	307	288	435	35	23	160

Comparison of Effectiveness of Machine Treatment and Manual Treatment of Seed

To determine the effectiveness of seed-treating machines in giving adequate coverage of fungicides, seed treated by a Gustafson seed treater was compared with seed treated by hand in the laboratory. The rate applied in the laboratory was two ounces per bushel of seed and the average dosage for the machine was approximately 1.5 ounces. Fifty-five lots of the Green Giant were used in this test. Two replications of 50 seeds each were planted in the greenhouse. The results are presented in Table 22.

Table 22.—Comparative emergence of peas treated by the Gustafson seed treater and by manual treatment, and planted in the greenhouse in 1944-1945.

Seed lot	Seed treatment[1]		
	Machine	Laboratory	Check
	%	%	%
D616K-2	56	58	4
F672MRR	49	53	15
A648L	80	69	1
F673M	42	38	15
F674M	43	43	14
F673MRR	41	57	11
F674MRR	69	68	17
D619K	47	32	3
F672M	73	46	7
F675M	46	27	1
D627K	84	72	27
A641L	77	82	18
A642L	68	75	12
A645L	55	86	19
E660M	60	85	12
E660MRR	59	66	10
E661M	51	72	12
E661MRR	42	62	10
E662M	74	74	23
E662MRR	41	60	12
E663M	81	82	28
E663MRR	50	58	17
D600L	58	57	26
D602L	69	81	24
D612K	51	76	7
D617-1	59	69	9
D610K	47	62	3
D646M	41	56	4
F670M	62	56	7
F670MRR	67	79	39
F671M	82	87	31
F671MRR	75	72	40
D600M	89	96	61
D601L	83	83	69
D601M	98	96	71
D602M	85	94	75

(Continued on next page)

Table 22 (Continued)

Seed lot	Seed treatment[1]		
	Machine	Laboratory	Check
D602MRR	91	89	69
D609M	92	92	76
D610M	95	96	77
D614M	95	94	78
D623K	88	100	78
D640M	95	96	85
D640MRR	82	91	71
D641M	98	92	87
D642M	64	76	9
D642MRR	40	68	5
B650M	39	63	5
B650MRR	45	65	2
E661L	50	54	3
E662L	33	68	3
E664L	58	61	10
E665L	50	78	18
D615K	78	68	19
D617K-3	74	75	31
A640K	77	86	42
Average	65	72	28

[1] r for laboratory and untreated = 0.658.
r for 63 degrees of freedom at the 1-per-cent level = 0.348.

From Table 22, it can be noted that the average emergence for all seed lots was 28, 65, and 72 per cent for untreated, machine-treated, and laboratory-treated seed, respectively. The two methods of treating seed did not differ very much. Both methods of treatment gave approximately 200 per cent greater emergence over the checks.

The correlation coefficient value between emergence of peas from untreated seed and that treated with Spergon (in the laboratory) is highly significant. This value for r is 0.658, which is beyond the r value of 0.348 at the 1-per-cent level. Thus seed with greater vigor will produce larger stands when treated than will poorer seed. In other words, seed treatment did not equalize the stands from poor to good lots of seed. These results, of course, were obtained under rather severe greenhouse conditions, as is evident in Table 22. It is of interest to note in addition the great variation in emergence of the 55 seed lots of the same variety of peas.

Improvement of Stands through Treatment of Low-Test Seed

The variation within lots of a variety of peas as noted incidentally in the preceding experiments and as affecting the value of seed treatment was not to be overlooked. Five lots of the Green Giant variety and five lots of Alaska peas ranging in laboratory germination from 63 to 96 per cent were used in this experiment. The Green Giant seed lots included D616J, D613JRR, A650JRR, D611JW, and D640JRR,

Table 23.—Average percentage emergence of five germination lots of Alaska peas treated with chemical compounds and planted in the field at Pullman, Washington, in 1942.

Seed treatment (dosage)	Seed lot and laboratory germination percentages					Average increase over check
	1619 (96)	1611 (87)	1789 (86)	1755 (77)	1599 (67)	
	%	%	%	%	%	%
Untreated check	64	39	21	36	11	0
Semesan (0.25%)	91	87	64	61	44	37
Spergon (0.25%)	91	87	75	70	44	40
Red Cuprocide (0.25%)	94	74	75	67	37	39
New Improved Ceresan (0.25%)	92	74	75	67	37	37
Calcium cyanamide (0.125%)	53	28	—	—	—	–21
Calcium cyanamide (0.0625%)	56	26	—	—	—	–20

showing laboratory germination tests of 96, 93, 88, 83, and 63 per cent, respectively. The Alaska seed lots, showing a similar range of laboratory germination levels, were 1619, 1611, 1789, 1755, and 1599, producing 96, 87, 86, 77, and 67 per cent, respectively, of vigorous seedlings. These experiments were conducted in the fields using Spergon, Semesan, Cuprocide, and New Improved Ceresan as seed treatments. Each seed treatment and seed lot was run in quadruplicate. In determining the vigor of the five lots (D601K-2, D623K, D629K, D629JRR, and D615J) used in the storage experiment, a comparison of the two methods—laboratory and field tests—was made.

From Table 2, the emergence for the untreated checks for seed lots D616J, D613JRR, A650JRR, D611JW, and D640JRR is 73, 36, 41, 35, and 12 plants, respectively. This does not conform too closely with their respective laboratory values of 96, 93, 88, 83, and 63 per cent. Using one fungicide, Spergon, as an example, stands for these seed lots in the same order presented above were 84, 75, 74, 83, and 52. The results for the best and poorest lots conform with the laboratory tests; this is not true for the intermediate groups. According to the field data, Lot No. D611JW is the second best, whereas the laboratory germination tests indicate it to be fourth in rank. Probably a difference of about 10 per cent in the laboratory test should not be considered significantly different insofar as wrinkled peas are concerned.

The five lots of Alaska (smooth seed) peas showed closer agreement between the two germination tests than did the Green Giant (wrinkled seed) peas, as recorded in Table 23. For those showing 96, 87, 86, and 67 per cent test in the laboratory, emergence produced in the field was 64, 39, 21, 36, and 11 per cent from untreated seed and 91, 87, 64, 61, and 44 per cent from Spergon-treated seed, respectively. The results with the treated seed brought out the fact that the laboratory test indicated the potential vigor of the several seed lots of Alaska peas which was not sufficiently evident from the untreated checks.

Table 24.—Average yield of peas in bushels per acre as influenced by seed treatment and weeding in field trials at Dayton, Washington, 1945.

Field treatment	Seed treatment	Yield	Per cent of increase over untreated check
Weeded	Spergon	14.1	20.5
Weeded	Untreated	11.7	
Not weeded	Spergon	4.7	67.9
Not weeded	Untreated	2.8	

Table 25.—Average yield of peas in bushels per acre as influenced by seed treatment and weeding in field trials at Pullman, Washington, 1945.

Field treatment	Seed treatment	Yield	Per cent of increase over untreated check
Weeded	Spergon	10.7	32.1
Weeded	Untreated	8.1	
Not weeded	Spergon	4.8	65.5
Not weeded	Untreated	2.9	

Yield Increases Due to Seed Treatment in Plots Weeded and Not Weeded

To determine the value of seed treatment in increasing yield of peas under more actual field conditions, an experiment was set up with plots that were not weeded. Combinations of these two variables with treated (Spergon) seed and untreated checks were made. Three replicates, using Green Giant seed, were run of each of the four possible combinations. These were planted in a random fashion within each block. Each plot consisted of ten rows of 18 feet, each with 100 seeds per row. At Dayton, Washington, the plots were planted on April 15, weeded by hand on June 15, and dry yield was taken on July 17, 1945. At Pullman, Washington, the plots were sown on May 2, weeded by hand on July 7, and harvested on August 10, 1945. The results of this experiment are recorded in Tables 24 and 25.

In experiments such as those in which the plots are thoroughly weeded, increases in yield due to seed treatment with Spergon of 20.5 and 32.1 per cent resulted at Dayton and Pullman, respectively. On the other hand, under more actual field conditions in which thorough weeding is not practiced, increases of 67.9 and 65.5 per cent were obtained at the two respective locations. In other words, greater increases from seed treatment under practical field conditions can be expected than are reported by research workers in experiment stations.

Table 26.—Effect of seed treatment on the amount of root and foot rot of five seed lots in greenhouse trials, three weeks after emergence, 1942-1943.

Treatment and dosage	Plants affected				
	D601K-2	D623K	D629K	D629JRR	D615J
	%	%	%	%	%
Untreated checks	10	8	7	17	24
Spergon (0.25%)	3	2	2	4	9
Dubay 1205 FF (0.25%)	2	3	3	3	8
Dubay 1205 AK (0.25%)	4	5	4	4	8
New Improved Ceresan (0.125%)	1	5	4	7	12
Semesan (0.25%)	2	1	1	5	4
Dubay 1205 AL (0.25%)	2	—	—	4	8
Micronized copper (0.25%)	5	2	3	7	2
Yellow Cuprocide (0.25%)	2	0	0	1	12
Dowicide B (0.50%)	1	0	0	3	17
Micronized sulphur (0.25%)	14	19	13	18	25

Residual Effect of Fungicides on the Amount of Foot and Root Rot in Peas

The question frequently arises as to the extent to which seed treatment of peas affords protection from soil-borne organisms for the seedlings following emergence. To investigate this point, a series of experiments was set up.

In 24 separate greenhouse tests in 1942-1943, a classification was attempted according to the amount of tip blight, foot rot, root rot, and healthy plants. Tip blight refers to the killing of the growing point or tip of the shoot. Foot rot denotes lesions on the stem from the cotyledons to just above the ground line, and root rot to decay below the cotyledons. Ten seed protectants were included: Spergon, Dubay 1205 AK, Dubay 1205 FF, Dubay 1205 AL, New Improved Ceresan, Semesan, Micronized copper, Micronized sulphur, Yellow Cuprocide, and Dowicide B. Five lots of the Green Giant variety were studied: D601K-2, D623K, D629K, D629JRR, and D615J. Data were taken four weeks after the planting was made, and are summarized in Table 26.

An experiment similar to the preceding one was set up to test the post-emergence protection afforded by seed treatments under field conditions. The results of the field test are presented in Table 27.

In the greenhouse trials in 1942-1943, as recorded in Table 26, the amount of root and foot rot is greater in the untreated than in the treated rows. This is in conformity with the findings of others (*9*, *10*, *14*). Micronized sulphur is an exception. There is no apparent difference in the residual effect through the use of any one of the better fungicides. From the field trials, as reported in Table 27, no conclusions can be drawn relative to residual effect. Results are based on dupli-

Table 27.—Effect of seed treatment on the amount of root and foot rot of five seed lots in field trials at Dayton, Washington, 1943.

Treatment and dosage	Plants affected				
	D601K-2	D623K	D629K	D629JRR	D615J
	%	%	%	%	%
Untreated check	75	100	85	80	90
Dubay 1205 FF (0.2%)	95	75	80	90	90
New Improved Ceresan (0.125%)	100	95	90	80	100
Semesan (0.3%)	100	85	75	80	80
Dubay 1205 AK (0.25%)	85	100	90	100	100
Spergon (0.2%)	90	95	90	90	65
Micronized copper (0.2%)	100	100	100	85	70
Micronized sulphur (0.2%)	100	100	90	80	95
Yellow Cuprocide (0.2%)	90	80	100	80	90

cates collected nine weeks after planting. It is quite possible that readings of the percentage of root and foot rot should have been taken sooner after planting.

Another greenhouse test similar to the preceding was considered feasible in 1945 in a case where damping-off was less severe. The percentage of plants with foot rot not arising from cotyledonary infection was recorded for untreated and treated pea seed of 12 seed lots of the Green Giant variety. Spergon was applied at the rate of 2 ounces per bushel. The seed was planted on March 29, 1945, and data taken on April 28, 1945. The 1945 greenhouse results were even more striking than those from the 1942-1943 tests. In the 1945 greenhouse experiment the number of plants with foot rot was 30.5 and 3.7 per cent for untreated and Spergon-treated seed, respectively. The amount of foot rot in the 1942-1943 tests was 13 and 4 per cent for the respective treatments. Furthermore, it was seen that seed lots within a variety vary in their susceptibility to the disease, ranging from 16 to 50 per cent of plants infected.

The Weights of Seedling as a Measure of Seed-Treatment Benefits

An indirect manner of measuring protection resulting from seed treatment was that of obtaining the green weight and finally the yield of plants from treated seed. An experiment was set up at Pullman to determine the influence of Spergon seed treatment on the resulting stands. Three blocks were planted with ten replicates of 100 seed per 18-foot row of paired treated and untreated rows in each block. Each pair of treatments was alternated with a border row. At weekly intervals a pair from each block was collected. The first collection was made on May 27, 1944. The green weights of eight collections of the plants were taken after cutting them just above the cotyledonary attachment. The ninth collection consisted of green pods and the tenth of dry shelled peas. At the same time data were recorded from

Table 28.—Crop weights and percentage of diseased stems of plants resulting from treated (Spergon) and untreated pea seed, determined at eight weekly intervals. Ninth collection consisted of green pods; tenth, of dry peas.

Collection No.	Percentage of emerged plants with stem lesions: Check	Percentage of emerged plants with stem lesions: Spergon treated	Average weight (in grams) Untreated: Per row	Untreated: Per plant	Spergon: Per row	Spergon: Per plant	Weight per row of check expressed in percentage of treated	Weight per plant of check expressed in percentage of treated
	%	%						
1. Plants	13.2	2.1	31	0.66	46	0.77	66	86
2. Plants	11.6	9.4	85	1.62	110	1.62	77	100
3. Plants	11.8	4.4	216	3.28	329	3.92	65	84
4. Plants	19.2	8.2	468	8.67	737	8.99	64	96
5. Plants	13.7	7.8	1023	16.77	1433	17.20	71	98
6. Plants	14.8	6.0	1673	30.98	2017	24.30	83	127
7. Plants	20.2	9.2	1962	33.25	2423	29.19	81	114
8. Plants	12.2	11.1	1932	39.43	2533	33.77	76	117
9. Green pods	—	—	673	14.96	990	13.20	68	113
10. Dry peas	—	—	217	4.43	252	3.37	86	134
Average	14.8	7.5						

this study to show the number of plants with stem lesions from treated and untreated seed. The results are presented in Table 28. A seed-treating material may act as a stimulant, protectant, or as a nutritional element. In analyzing the results, it is difficult to determine whether beneficial results are due entirely to one or more of these factors.

Table 28 shows that the total weights from rows sown with Spergon-treated seed were consistently heavier than those from untreated rows. There is a tendency for the treated to increase in weight over the untreated for most of the growing period. The final yield of dry peas from treated seed was greater than untreated seed by an average of 188 pounds per acre.

It will also be noticed that the average weight of individual plants from Spergon-treated seed is greater than from untreated seed up to and including the fifth collection. Thereafter, the plants from untreated seed were heavier. The weights of the green pods of the ninth collection were greater on the average for plants from untreated seed than from treated seed. Due to the thinner stand in the rows, the plants from untreated seed began to stool considerably about the time the fifth or sixth collection was made, or about six or seven weeks after planting. It is interesting to note, however, that the difference in individual weight did not compensate for the difference in stand, as the yield per row for treated seed was 35 grams more than for untreated seed.

The plants from Spergon-treated seed showed 7.5 per cent with stem lesions in contrast to 14.8 per cent in the plants from untreated

Table 29.—Effect of Arasan and Spergon applied at the rate of two ounces per bushel on nodulation of peas, 1943.

Seed treatment	Percentage of plants with nodules
No treatment	27.0
"Nitragin" only	100.0
Arasan only	0.0
Spergon only	0.0
"Nitragin" + Arasan	100.0
"Nitragin" + Spergon	50.0

seed. This is in accord with results obtained in two previous greenhouse plantings. Increase in yield may in part be attributed to Spergon treatment. The factor of stimulation can well be explained by the last column of Table 28. Here there are slight differences between the weights per plant from treated and untreated seed up to and including the fifth collection. After this collection the weights of individual plants from untreated seed was greater than from the treated seed due, as assumed above, to stooling of plants because there were less plants per unit area. Whether it was "stimulation" or disease control causing the difference in individual weights of plants cannot be determined from these experiments. Planting in sterilized soil would be necessary to distinguish between "stimulation" and disease control.

COMPATABILITY OF SEED-TREATING MATERIALS AND NITROGEN-FIXING BACTERIA

The feasibility of inoculating treated seed with legume bacteria is of importance to growers. Jones and Wade (7) in California stated that Red Cuprocide, 2% Ceresan, and Semesan were too toxic to the bacteria to be used, while Appleman (1) in 1942 found Semesan was compatible. McNew and Hofer (11) considered Spergon somewhat toxic to the bacteria but found it could be applied at the rate of 1.5 ounces per bushel of seed without too much damage to the bacteria. The present study in regard to this matter included only Arasan and Spergon. To determine if Spergon and Arasan are compatible with nitrogen-fixing bacteria, seeds of the Green Giant pea were treated with either Spergon or Arasan, and followed by an application of nitrogen-fixing bacteria in the form of the commercial "Nitragin," applied at the rate and by the method recommended with the product. The seed thus treated was planted in steam-sterilized soil on March 18, 1944. The same fungicides were applied at the rate of 2 ounces per bushel on the seed sown on March 21, 1943. The seed was planted in six-inch pots within a few hours after treatment, using four replicates of 25 seeds each. Readings of the number of plants showing nodulation were made four weeks after planting the seed, and the data obtained are recorded in Table 29.

The above experiment was run on a rather small scale and prob-

Table 30.—Effect of Spergon and Arasan applied at different rates of nodulation of peas in 1944.

Treatment	Dosage of Chemical	Percentage of plants with nodules
Uninoculated untreated check	None	38
Nitragin only	None	71
Nitragin + Spergon	1.5 oz.	76
Nitragin + Spergon	2.0 oz.	77
Nitragin + Arasan	1.5 oz.	81
Nitragin + Arasan	2.0 oz.	75

ably does not yield sufficient evidence to draw conclusions. Since the untreated checks showed nodules on the roots, it may be assumed that some bacteria entered these pots, possible by splashing during watering. In combination with Arasan and Spergon, fairly good results were obtained, indicating that they have selective toxicity insofar as organisms are concerned. As a further test the experiment was repeated with modifications in 1944. The results of the second test are presented in Table 30.

Again, as in the previous experiment, Spergon and Arasan appear to be compatible to a certain extent with the nitrogen-fixing bacteria. There is no apparent difference in the rate of chemical application as expressed in the number of plants producing nodules. This is not in agreement with the results of McNew *et al* (*11*) who claim that Spergon applied to peas at the rate of greater than 1.5 ounces per bushel is too toxic for commercial practice. Since the uninoculated, untreated checks showed nodulation, though half as much as the Nitragin-treated, the results again are not too conclusive. Although the experiment was carefully planned and executed, contamination apparently occurred. Possibly the bacteria entered through the air or through the water system, or were within the seed. Nevertheless, it would not be amiss to assume that Spergon and Arasan are compatible with legume bacteria, for these treatments did not decrease the amount of nodulation compared to the Nitragin-treated seed.

DISCUSSION

It is apparent from the foregoing results that *Fusarium solani* f. *pisi* is the most important organism causing root and stem rot of peas in Washington. It also can cause severe pre-emergence damping-off. F. R. Jones (*6*) in 1923 stated that this organism is distributed throughout most of the pea-growing areas of the United States. His statement did not include any of the Pacific Northwest except Idaho, where the organism was not recognized at that time. Since the Palouse country includes the pea-growing section of Idaho as well as the major part of the pea-growing area of Washington, it is probable that this organism occurs also in Idaho, for *Fusarium solani* f. *pisi* was obtained from 50 per cent of the

isolations. Harter (*4*) in 1938 reported *Fusarium coeruleum* in Idaho as causing seed decay and root rot of peas. This organism is considered similar to *Fusarium solani* f. *pisi*, according to the latest classification of *Fusaria* (15). The same organism was isolated consistently from lesions on the stems of peas during the course of the growing season. Evidence points to the fact that this organism should be classed as soil-inhabiting and not as a soil invader.

Other fungi of lesser importance on peas in Washington included *Fusarium oxysporum, Fusarium equiseti, Sclerotinia* spp., and a species of *Phoma* tentatively classified as *Phoma conidiogena.* The last two pathogens were found present on the seeds as well as being soil-borne, indicating a probable means of dissemination.

The cultures of *Fusarium solani* f. *pisi* showed the existence of physiologic strains as regards virulence, causing stand reduction from 0 to 80 per cent. Jones (*6*) suggested that his work indicated the existence of physiological varieties of the organism.

Factors that were shown to influence the incidence of the diseases studied included, among other things, varietal differences of peas as well as differences in seed lots within a variety. Wrinkled peas are more susceptible than smooth peas. A highly significant correlation coefficient value resulted between emergence from untreated seed and seed treated of 55 seed lots of the same variety. Differences within a variety were attributed to vitalitiy of seed of different lots of seed and to seed-coat injury. Generally speaking, laboratory germination tests did not necessarily indicate possible field performance of a seed lot, being especially true for the wrinkled pea variety. Seed-coat injury and poor emergence were directly related. The cracks apparently give soil-borne organisms ready access to the inside of the seed before the seedling has a chance to become established. Furthermore, these injured areas may be ideal places for seed-borne fungi to lodge and later cause damping-off during germination. This injury to the seed coat occurs during the threshing, drilling, and cleaning processes.

In addition to the factors mentioned, various environmental factors affect the incidence of disease. Dissipation or a decrease in potency of seed protectants may occur if the soil is watered immediately after seeding; this was found to be the case with compounds like Dubay 1205 FF, Arasan, Spergon, and New Improved Ceresan. Under dry soil conditions, New Improved Ceresan caused root injury, preventing the proper formation of secondary roots. On experiments with different dates of seeding, seed treatment proved to be most effective during the earlier planting. Response to seed treatment is greatest during the adverse conditions. Seed that emerged more slowly from the soil produced poorer stands than otherwise, due to the longer period of time for attack by organisms. Response to seed treatment was therefore greatest under the poorest growing conditions.

A knowledge of the effect of storage time on the longevity and vitality of treated seed is important. The practice of treating the seed immediately after cleaning and processing and then storing would be more practicable and saving of labor. Therefore, it is desirable that the seed protectant be stable and not phytotoxic to seed in storage. These conditions were fulfilled in the present experiments by treatment of the seed with any one of several chemical compounds. Of the eight fungicides tried, Spergon, Semesan, Dubay 1205 FF, Dubay 1205 AK, and Yellow Cuprocide contributed to significant increases in stands for the 1941 stored seed when sown at two locations in the field in eastern Washington. New Improved Ceresan and Micronized copper were not effective in all cases and Micronized sulphur was ineffective. Increases in stand, from treated and stored 1942 lots of seed, were less spectacular. Of the eight treatments, only Micronized sulphur caused a significant decrease. Significant increases in yield resulted from seven treating materials used on 1941 seed after storage for six months. Increases in yield due to seed treatment for other storage periods were present, but the results were not significant.

Greater relative increases in stand resulted from seed treatment as the seed became older and decreased in vitality. In greenhouse plantings, percentage increases in stand in the field sowings reached as high as 317 per cent for the 1941 seed and 41 per cent for 1942 seed. In greenhouse plantings, increases as high as 684 and 284 per cent over the check for the respective seed lots were obtained. Treatment of seed did not equalize the differences in vitality between the 1941 and 1942 seed, however.

During the course of the storage experiment, periodic germination tests in the laboratory were run parallel with the field plantings. Laboratory germination results do not always indicate what performance may be expected in the field. A possible explanation may be due to the higher percentage of seed-coat injury of seed lots, which were significantly inferior in field trials, although they appeared by laboratory experiments to be the best seed.

Quite often in seed treatment tests significant increases in stand are obtained, but not in yield. Seed treatment increased yield in plots, in which thorough weeding was not practiced, by 68 and 66 per cent at two locations. On the other hand, yield increases of only one third to one half this amount resulted under conditions of thorough weeding. Weed competition prevents the plants in thin stands from stooling out to thus compensate for the thinner stands.

Protection of cotyledons seems especially desirable in peas, for there is a certain period when the young seedling requires the food stored in them. This critical period depends on the time it takes for the seedling to emerge and become wholly independent, and may be as much as three weeks. It should be apparent that an ideal seed protectant should be retained by the seed and remain potent in the soil at least this length of time.

In greenhouse trials in 1943 seed treatment decreased the amount of root and foot rot. Two years later, the residual protective effect was even more pronounced, the percentage of plants with foot rot being 10 times more from untreated seed than from treated seed. However, in field trials in 1943 no residual protective effect was noted, the disease being so severe that even treated seed produced poor plants.

This residual protection was measured by obtaining weights of plants during the progress of growth. Individual plants from treated seed were greater than from untreated seed up to the fifth week after emergence. Thereafter the plants from untreated seed were heavier, being able to compensate for the difference because of less competition for moisture and nutrients.

Compatability of pea-seed protectant and nitrogen-fixing bacteria is necessary. Other workers (*1*, *7*, *11*) have found some fungicides that did have and many that did not have this characteristic. The present tests showed seed treated with either Arasan or Spergon at the rate of 1.5 or 2.0 ounces per bushel and then followed by an application of commercial "Nitragin" produced plants with approximately the same number of nodules per plant as did seed not treated with the fungicides. Thus a reasonable degree of compatability of the two seed treatments with nitrogen-fixing bacteria is indicated.

SUMMARY

1. Stem and root rot of peas caused by *Fusarium solani* f. *pisi* is very prevalent in pea fields in the Palouse and Blue Mountain areas of Washington. The organism can also cause seed decay in the soil. *Fusarium oxysporum* and *Fusarium equiseti* and species of *Phoma* and *Sclerotinia* are less important in the cause of seed decay, root and stem rot.

2. Apparently pathogenically different strains of *Fusarium solani* f. *pisi* were found.

3. Watering immediately after sowing caused apparent dissipation or decrease in potency of certain seed protectants such as Spergon, Arasan, and New Improved Ceresan.

4. Emergence from Alaska and Green Giant peas sown at a shallow depth was significantly less than from seed sown deeper. This was due to a drier surface layer of soil. The increase in stand of treated over untreated seed was greater for the three- than the one-inch depth.

5. At Dayton the fourth date of planting of Green Giant peas produced the thinnest stand, being significantly less than that from the first and second dates of sowing but not the third. At Pullman, the third planting gave significantly poorer stands than did the first, second, and fourth plantings which were not significantly different from each

other. Seed treatment was highly significant at Pullman but not at Dayton. Using the Alaska variety, the earliest planting gave the poorest emergence. Response to seed treatment proved the greatest during adverse conditions.

6. Much seed-coat injury sometimes arises from threshing and cleaning processes. This injury may also occur to some extent naturally.

7. The water dip method and the iodine stain baths proved valuable in detecting cracks in the testas of pea seed. Determination of seed-coat injury by the dry method was inadequate in this regard.

8. A direct relationship was demonstrated between the percentage of seeds with cracked coats in a lot and the apparent susceptibility to attack by soil-borne organisms. This condition can be alleviated to a great extent by seed treatment.

9. Laboratory germination tests were only a fair criterion in judging the performance of a seed lot in the field. The percentage of seed-coat injury should be had in addition. Highly significant correlation coefficients resulted for emergence from untreated seed and treated seed of 55 seed lots of the same variety. Seed treatment did not completely compensate for loss of vitality due to age of the seed.

10. Pea seed was treated and stored safety for 30 months with Spergon, Semesan, Yellow Cuprocide, Micronized copper, Dubay 1205 AK (Arasan), and Dubay 1205 FF (Thiosan). New Improved Ceresan and Micronized sulphur were not safe under all conditions.

11. Plants from treated seed showed less stem and root rot due to the residual effect of the treating material. The residual effect was not noticeable in plants beyond the age of nine weeks. Increase in green weights of plants from treated seed could not be attributed solely to "stimulation" or to disease control.

12. Spergon and Arasan were compatible with inoculation of pea seed with nitrogen-fixing bacteria; application at the rate of 1.5 ounces per bushel of inoculated seed was relatively safe in the present experiments.

13. Spergon used at 1.1 ounces per bushel was as effective as 2.0 ounces, although a dosage of 1.5 ounces could be assumed as possessing sufficient "margin of safety" above the minimum dosage.

14. Seed treatment doubled the yield over the checks in a plot not weeded as compared to pea yields in a plot thoroughly weeded.

15. Spergon, although not ideal, was found to be the best seed protectant for peas of the various materials studied. Dowicide 5, which is similar to Spergon in appearance and physical properties, has not been given adequate tests to make final conclusions. Arasan, which is as effective as Spergon, is toxic or irritating to many persons using it.

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